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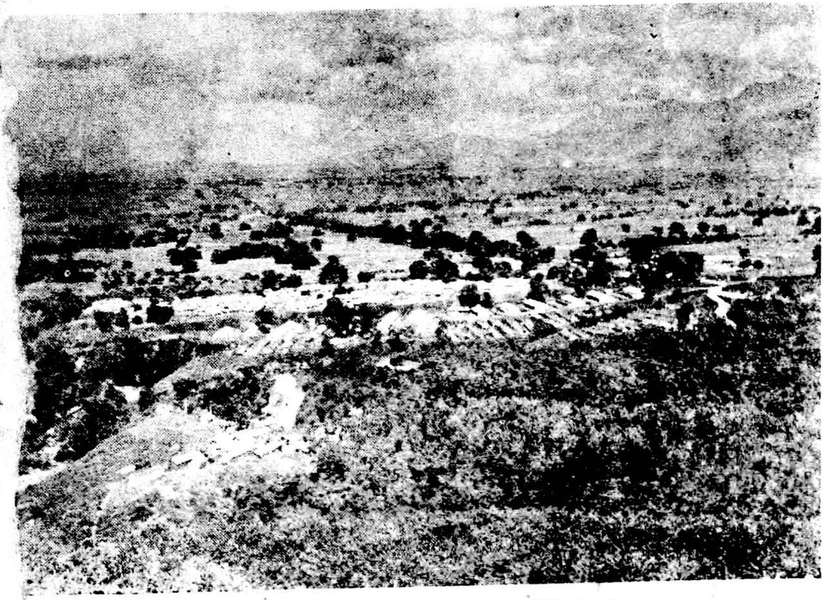
OF THE
ELECTRICITY DEPARTMENT
GOVERNMENT OF MADRAS

Vol. X OCTOBER—DECEMBER 1955 No. 3



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JOURNAL

OF THE ELECTRICITY DEPARTMENT GOVERNMENT OF MADRAS

VOL. X — OCTOBER—DECEMBER 1955 — No. 3

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NOTES FOR THE GUIDANCE OF AUTHORS OF ARTICLES CONTRIBUTED FOR THE JOURNAL

Articles or papers should be authoritative and when describing works, the information should be accurate. *Normally, articles* or papers, already published in other journals are *not* accepted. In any case, the fact of the articles or any part thereof having been *published previously* must be indicated clearly in the forwarding letter. All manuscripts should be typewritten (double spacing) on one side of the *paper only*, with a *margin* of *at least* two inches. Manuscripts must bear the signature of the author (or the signatures of the authors). The title of the paper should not be long. If necessary, use a main title and a sub-title. No abbreviation should be used except those of a universal character. Numbers given to equations and *formulæ in an* article or paper should be assigned in order of occurrence in the paper. Symbols should be in accordance with the standard notations, unless *there is specific* reason for the contrary The meaning of each symbol should be explained where first used and in case many symbols are used, a list should be *provided* in addition, in the beginning. Detailed references should be given *to* quotations. If numerous, these can be collected at the end, otherwise *these should* be placed as footnotes. References should be indicated by numbers, e.g., (4), (5), etc. Explanations given in footnotes should be indicated by signs, e.g., *, †, and not by numbers.

The authors of papers and articles are requested *to scrutinize* carefully the typed or cyclostyled copies before forwarding them. Equations and formulæ are best inserted in hand. Two sets *of drawings should* accompany an article. One set should be mere line-work without any lettering and the other complete with lettering, the former preferably on tracing cloth. Colour wash or line and pencil shades cannot be reproduced in line blocks. They should be replaced by hatching and colour lines by dashed chain or thicker black *lines*. The size of drawings or line blocks should generally be double the size to be reproduced in print.

It is desirable that the use of the first person should be avoided. When a specific statement is to be made, it should be written : "The author submits . . . . . ", "The author holds the opinion . . . . . . ", etc. It is desirable that articles or papers should be sectionalized by giving suitable 'sectional headings'. Avoid long and involved sentences ; short sentences are more effective and less likely to be misinterpreted. Do not begin a new sentence with a numeral, write the number in full as word. Place zero before the decimal point when the figure represents something less than unity ; thus :—0·75. Place a comma to mark the thousands in number of four figures and more ; thus : 2,127,356, and, in the case of Rs. thus : 27,26,127. Do not write in the text of the article 8′ 6″ by 4′ 3″ but as 8 feet 6 inches by 4 feet 3 inches or as 8·5 feet by 4·25 feet. For numbers under 10—write out in full, if not followed by an abbreviation ; thus, write nine days, but 9 lb., not nine lb. For numbers over ten use numerals thus : 50 days.

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ANNOUNCEMENT

The Editor, Madras Electricity Department Journal, hereby acknowledges the receipt of a cheque for Rs. 1,328–12–0 sent by Sri B. R. Somayajulu, President, Yoganandam Memorial Committee, Madras-6, being the amount set apart for the purpose of awarding prizes annually for the best technical original article in the Journal of the Government Electricity Department, from the Yoganandam Memorial Prize Funds.

To commemorate the name of late Sri Yoganandam, it had been decided by the Yoganandam Memorial Committee to institute a Prize called the "Yoganandam Memorial Prize" to be awarded annually to the best original technical article published in this Journal. The prize will be awarded from the interest accruing from the sum set apart for the purpose.

According to the rules, drafted by the Advisory Committee, an article for meriting the prize should deal with any one of the following subjects:—

(*a*) Report of practical occurrings in the engineering side of the Electricity Department Systems, in which the author had practical experience and responsibility of operation and/or erection or execution, and in which occurrings he has shown commendable ingenuity or originality,

(*b*) analysis or review of the engineering practice showing a high degree of comprehensiveness, analytical ability and constructive thought,

(*c*) theoretical contributions of engineering interest, showing originality of thought and ability, and likely to be of substantial practical use in the work of the Government Electricity Department.

(*d*) discussions and criticisms of the Departmental engineering practice, or procedure, or organizational methods, showing a thorough grasp of existing practice and of their existing defects or shortcomings and suggesting changes or modifications as will overcome such defects or shortcomings, or

(*e*) such other subject prescribed by the Prize Committee and duly notified from time to time to all the technical members of the Department at least 12 months prior to award of the prize.

The Prize is awarded by the Committee called the "Yoganandam Memorial Prize Committee", consisting of the following members:—

(1) The Chief Engineer for Electricity,

(2) The Chief Operation Engineers and

(3) Members, co-opted from time to time.

The Editor of the Journal functions as the Secretary.

The award of the prize may be in the form of cash or technical books of equivalent value as decided by the Prize Committee.

The decision of the Committee in the matter of selection of the article for awarding the prizes is final.

It has been decided that, to start with, a prize not exceeding Rs. 25 be given for the best article published during the year 1955-56.

K. M. KURUVILLA,

Editor.

Protective grounding against lightning with special reference to counterpoise earthing

By V. P. APPADURAI, B.A., M.I.E. (Ind.)
Chief Engineer for Electricity.

Introduction.—The voltage appearing at the top of a tower on a direct stroke of lightning either to the tower or to an earth conductor near the tower is equal to the product of the lightning surge current and the tower foot resistance. In the event of severe lightning surge the tower footing resistance governs the voltage appearing on the top of the tower and on any connected ground wire.

It is therefore very important that transmission structure grounding for protection against lightning should make use of a ground circuit having a low impedance to steep wave front surges.

Counterpoise earthing.—The counterpoise is a practical means of reducing the resistance by increased area of earth in contact with the grounding system. The method of burying below ground a bare conductor parallel to or at some angle to the line conductors and connecting up the same to the tower legs is known as 'counterpoise earthing'.

This method has been tried in Canada and the results fully came up to expectations. In the case of certain lines which showed an average of 11·2 lightning outages per 100 miles per year, the number was brought down to 2·8 after

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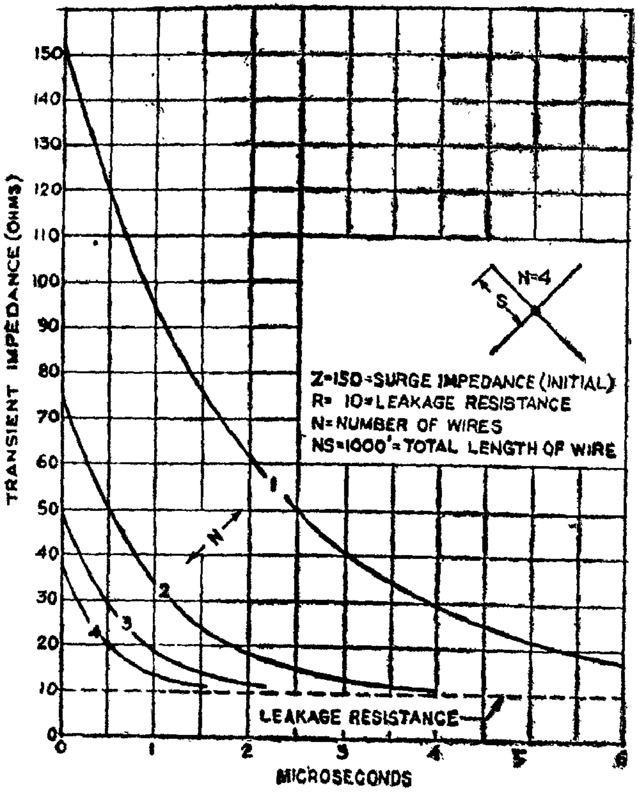
installation of continuous counterpoise on these lines.

Theory.—Rods up to 100 feet in length for grounding have inductances which are negligible in their effect on lightning discharges, and hence are satisfactory, if their resistances to ground are small. However, the surge impedance of a single conductor buried in soil of moderately high resistivity probably lies between 150 and 300 ohms. regardless of its termination. The effective impedance to a surge of a conductor and its termination decreases to a much reduced value in a time, which depends primarily on conductor length and secondarily on soil resistivity. The final impedance, because of ionization may be appreciably less than that measured with an earth tester. If the conductor length is greater than 200 feet the effective impedance may decrease too slowly to prevent a flash-over. Thus the principal effect in the behaviour of a counterpoise is the transient impedance. This begins with an initial surge impedance of 150 to 200 ohms. and decays in a roughly exponential fashion to its final leakage resistance, the time of transition being the time required for the first reflection to return from the end of the counterpoise to the tower, travelling at one-third the velocity of light. This time depends upon the length of the counterpoise and the speed of propagation of the surge. In general, the surge travels at approximately one-third the speed of light. In an aerial wire the velocity of propagation is about 1,000 feet per microsecond while in the counterpoise it will be about 333 feet/microsecond. Therefore a 1,000 feet counterpoise having an initial surge impedance of approximately 150 ohms, will have at the end of 6 microseconds an effective resistance equal to the leakage resistance. Likewise a 250 feet counterpoise having an initial impedance of 150 ohms. will reduce to its leakage impedance in 1·5 microseconds. This indicates the desirability of using many short counterpoises instead of one long counterpoise as the leakage resistance is dependent largely upon surface area so that this is the same, whether one 1,000 feet counterpoise or four 250 feet counterpoises are used. On the other hand the counterpoise of four 250 feet sections has an initial surge impedance of $\frac{150}{4}$ — 37·5 ohms. and reaches the final leakage resistance in 1·5 microseconds as compared to 150 ohms and 6 miscroseconds for the 1,000 feet counterpoise. Increasing the number of wires and decreasing the lengths result in two substantial gains, viz., reduction in surge impedance and shortening of the transition time. The curves of Fig. 1 illustrate the above.

However, the full benefit of additional conductors is not achieved because of mutual coupling, especially if more than four conductors are used. Also if the leakage resistance of the counterpoise is greater than its surge impedance a positive reflection returns from the termination to add to that portion of the surge voltage still present and may result in a flashover. For this reason, grounding conductors including those of a



EFFECT OF NUMBER OF WIRES ON THE COUNTERPOISE IMPEDANCE.

SKETCH 1.

crow foot counterpoise should always be terminated on electrodes having measured resistance of less than 150 ohms. When no satisfactory termination for a crow foot lead can be found before it meets that of the next structure, the leads from the first structure can be joined to those from the next, resulting in a continuous counterpoise.

In general, a counterpoise system should consist of sufficient wires to bring the impedance down to the value of the leakage resistance, if possible before the maximum voltage conditions can build up on the tower. The length in feet of the counterpoise need not be greater than the wave front in microseconds × 1,000/6.

Grounding practices and improvements.—Structure ground resistance of less than 15 ohms provide line service with very few lightning outages. However, no

single maximum value can be defined for all line structures. During line construction, footing resistances of each structure are measured and if any one is more than 25 ohms grounding improvement is undertaken. The preferred maximum value after improvement is 15 ohms. But a reduction in ground resistance below a certain value requires ever increasing effort and results in decreasing benefits. So, where the preferred value of 15 ohms cannot be obtained at an acceptable cost, a practical maximum value of 25 ohms is tolerated before continuous counterpoise is permitted as a last resort.

Grounding improvements.—The sequence of steps used to obtain grounding improvement is as follows:—

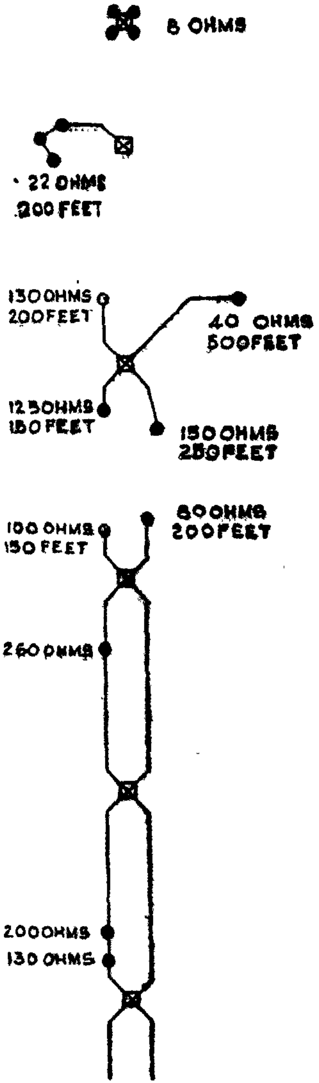
(1) Rods are driven at the structure, if this be possible. Resistance measurements taken after each section is driven, indicate the rate at which the resistance is being reduced. Where 15 ohms is obtained with relative ease, driving is continued until the rate of resistance reduction levels off.

(2) When a resistance below 15 ohms at the structure cannot be obtained, a search is made for a location where rods can be driven, and connected to the structure with less than 200 feet of conductor. If such a location be found, rods are driven in accordance with the previous paragraph. When their combined resistance is less than 25 ohms and no further reduction in resistance can be obtained economically, they are connected to the structure with buried conductor. When less than 25 ohms is not obtained, a second similar location is sought, and if found, the process is repeated.

(3) If a resistance of less than 25 ohms cannot be obtained within 200 feet of the structure, the possibility of installing crow foot leads and terminations is investigated. A crow foot consists of four conductors radiating from the structure, initially at right angles to each other, and subsequently kept at least 50 feet apart. Since each of these leads should terminate on an electrode of less than 150 ohms measured resistance, a search is made for possible rod locations not more than half a span distant from the structure. If such locations are found, rods are driven and their individual and combined resistances are measured. If each is below 150 ohms and the value of resistance of rods and structures combined is below 25 ohms buried conductors are installed and connected to the structures.

(4) When proper terminations for crow foot leads cannot be obtained, resistance measurements are made for record purposes. The leads are then connected, to those of the adjoining structures to form a continuous counterpoise.

Examples of these methods of grounding as applied to lines on single-structure are shown schematically in Sketch 2.



SCHEMATIC REPRESENTATION OF GROUNDING METHODS ORDER OF PREFERENCE IS FROM TOP TO BOTTOM.

SKETCH 2,

Various grounding details are shown schematically in Sketch 3.

Procedure of installation of grounds.—Tower footing resistance may be lowered to about five ohms within a mile of any station, a switching structure, or where unusual exposure takes place.

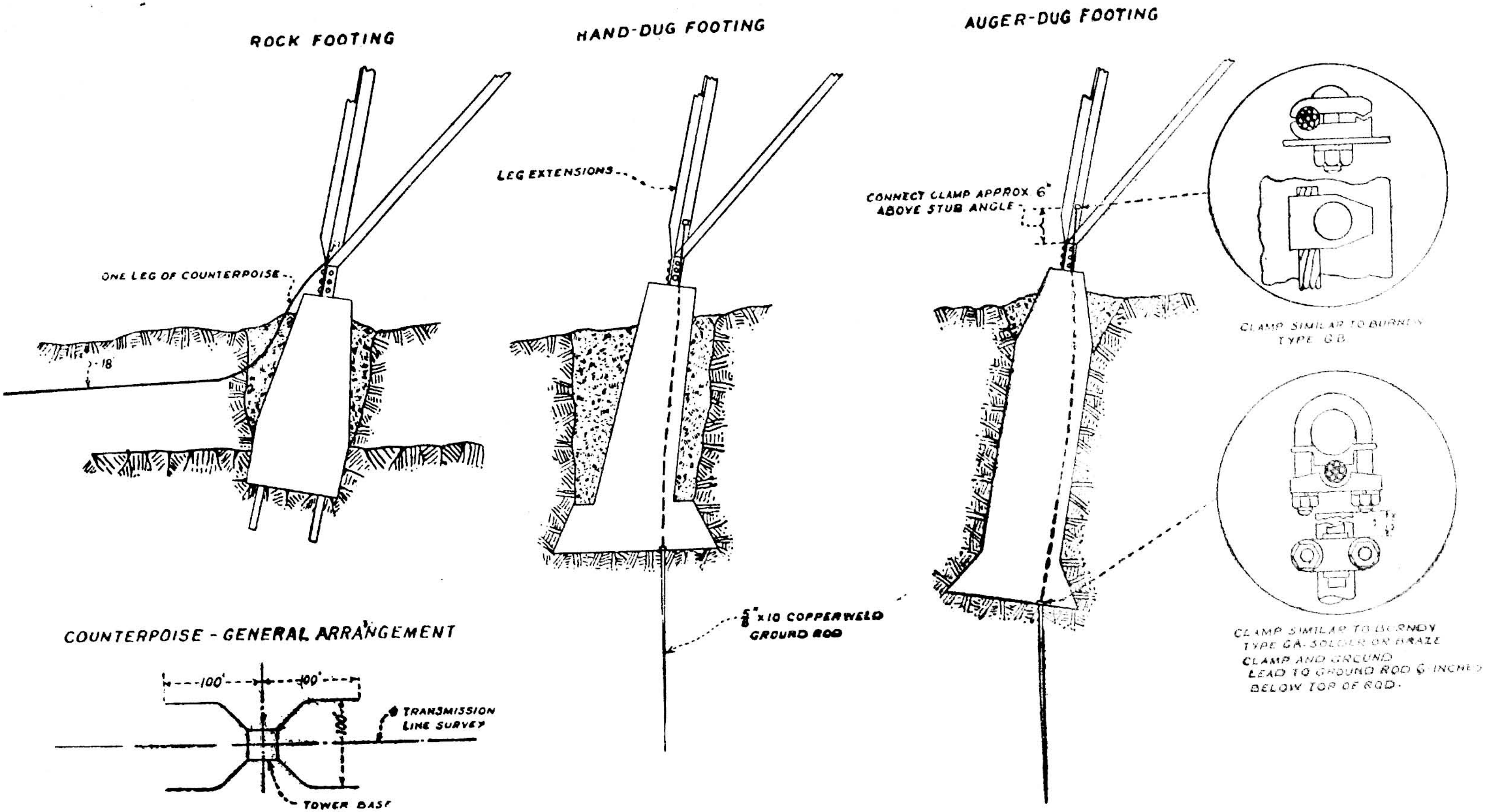
In other cases it should not normally exceed 15 ohms. If driving of ground rods is easy, this figure should be reduced to 10 ohms or less.

If when driving rods, a value of 25 ohms or less is obtained, and if it is evident that extra rods or further driving will not accomplish much, then nothing further should be done.

An exception to this would be exposed structures or those close to stations or points of weak insulation. In such cases counterpoise or other means of further lowering the resistance should be considered.

When the tower footing resistance is over 25 ohms and it is not possible to drive rods at the tower, examine the area around the tower for a suitable site so that the lead connecting the rods with the tower would not exceed about 200 feet in length. If this is possible, rods should be driven and as before, attempt to get 15 ohms or lower when driving is easy, or in difficult cases stopping below 25 ohms.

When it is not possible to obtain 25 ohms or less with a lead distance of 200 feet from the tower and with up to four leads, but a suitable location can be found at some greater distance, the ground



NOTES.

Install one ground rod under each footing. Ground wire to be imbedded in concrete along outside of reinforcing steel. Footings requiring piling shall be grounded in a manner similar to the methods shown on the left for footing without piling.

TOWER GROUNDING DETAILS.

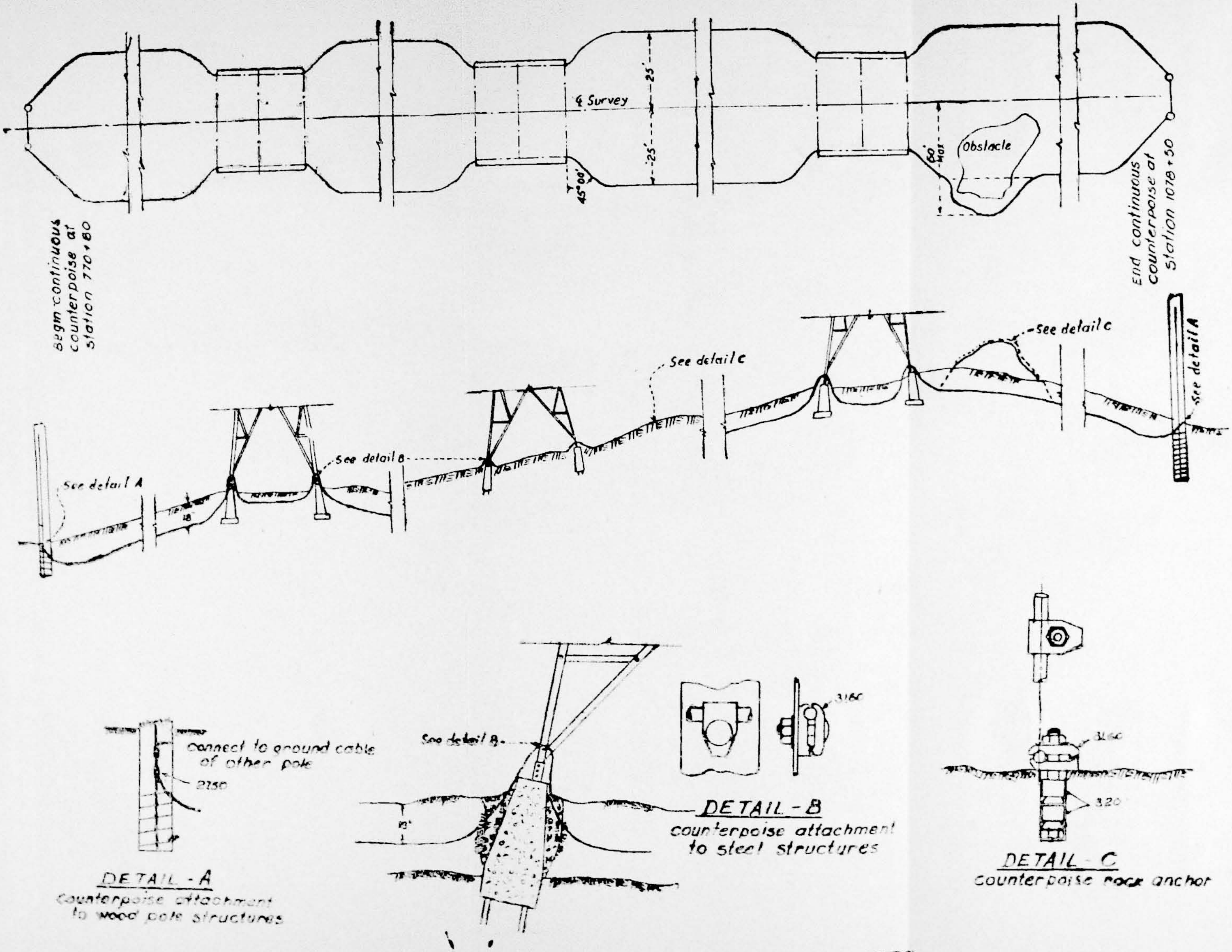
Sketch 3.

Summarising, the following may be adopted in practice :—

(i) Never terminate a counterpoise in an open end or in a resistance more than 150 ohms. If the terminating resistance exceeds this value, the counterpoise must be extended until such a value can be reached or else made continuous.

(ii) Always terminate a lead in a resistance less than its surge impedance.

(iii) If this cannot be done, extend the lead continuously tower to tower. The Sketch 5 shows the methods adopted under various conditions.



NOTES.

This counterpoise system is of the continuous, parallel, 2-wire type. The general construction details are shown by the drawings on the left. Where it is not practicable to bury the cables, the cables shall be laid on the surface in a manner which will provide a maximum of protection against mechanical injury and shall be anchored securely at intervals not to exceed 25 feet. Where obstacles, such as boulders or rock outcrops are encountered, the cables may be routed around them provided that the maximum distance from the centre line of the survey does not exceed 50 feet. If this distance cannot be maintained, the cable should be routed over the obstacle and anchored securely at critical points. For crossing stream beds, the cables should be buried or anchored securely in a manner which will provide the maximum protection to the cables.

2*

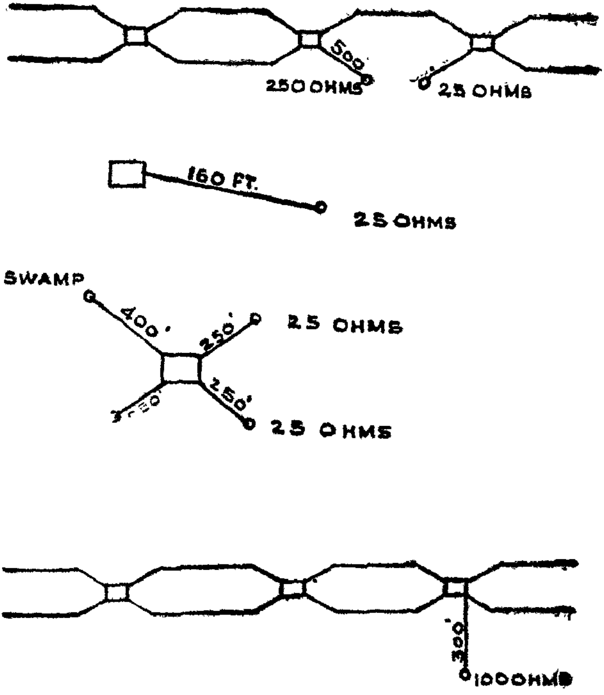
CONTINUOUS COUNTERPOISE DETAILS.

SKETCH 5.

should be driven and connected to the tower. Three additional leads should be connected to the tower and extended at 45° to the edges and thence parallel to the line to points where they may terminate on rods having a resistance less than the surge impedance of the lead (150 ohms). If suitable terminations are not found within half span length then the leads should be run down at a separation of not less than 50 feet and continuously from tower or tower. Rods should be driven at any point where a resistance less than 150 ohms might be obtained with relative ease.

Side leads may tap these main leads and run into nearby pockets of swamp or other low resistance area where such areas exist within an economic distance or the main lead may be diverted for short distances to obtain extra grounding. While a total of four leads may be adequate the number of leads may be up to six, if this is necessary to reduce the initial surge impedance to a low value. However, all leads must terminate in resistances less than 150 ohms.

The Sketch 4 gives some idea of the form which counterpoise systems can take.



SKETCH. 4

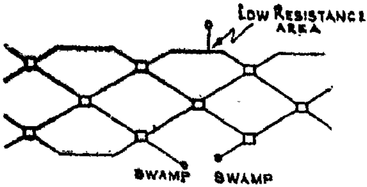
(iv) Reduce initial surge impedance below 40 ohms by use of additional lead.

(v) Keep grounds as close to the tower as possible.

(vi) Where the lead to good ground is longer than 200 feet, put on additional leads about 200 to 250 feet long to lower the initial surge impedance and terminate these additional leads in grounds of less than 150 ohms.

(vii) If all the above methods fail to produce results or are not applicable because of the general high resistance of the soil, a double continuous tower to tower counterpoise should be installed.

(viii) Where two or more lines run parallel to each other they may have their counterpoise systems interconnected—vide Sketch 6. Such interconnections will often provide a more economical arrangement and are very satisfactory if installed properly.



SKETCH. 6.

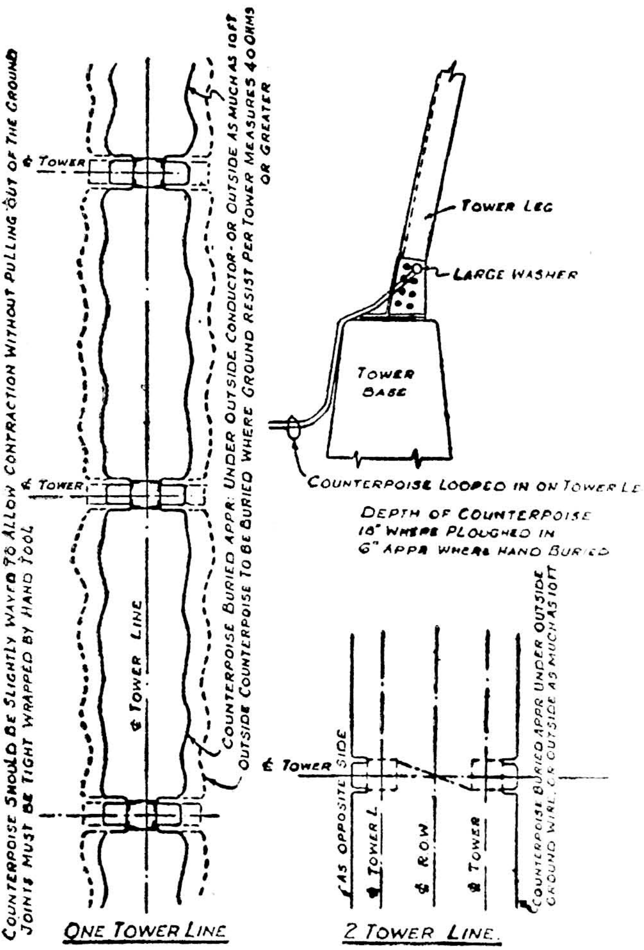
Counterpoise installations.— Counterpoises are installed in such stretches of transmission lines and in such lengths as required to bring the protection level to the desired extent. Generally not more than 20 per cent of the towers in any line require counterpoise.

The counterpoise wires shall be buried at depths varying from 6 inches to 12 inches in fair ground in rough country and to 18 inches in places likely to be cultivated. The depth does not materially affect the resistance of the counterpoise. It is necessary to bury the wire only deep enough to prevent theft.

Counterpoise should be slightly waved to allow contractions without pulling out of the ground joints and must be tight wrapped by hand tool.

Sketch 7 shows counterpoise installation on a location where counterpoise wires are provided for all steel tower lines. Galvanized steel 0·207 inch dia. 9·6 ohms per mile in resistance at 68°F and 625 lb. per mile in weight is used.

Each of these counterpoise wires will be connected to the tower footing by means of a cable suspension clamp. The clamps are to be attached to the footing steel work by removing one bolt in the connecting plate within the anchor angle and substituting a longer bolt for this purpose. In the case of towers with concrete footing, the connection should be made above the top of the concrete footing.



COUNTERPOISE INSTALLATION SPECIFICATION

SKETCH - 7

Service-Testing of H.T. meters

By S. RAMAN, B.E. (Hons.),
Assistant Engineer (Electrical).

1. Introduction.

In connecting up a H.T. meter to the circuit, an error in connection may occur with respect to either or both of the current and potential supplies to the meter.

With respect to the connection of the red and blue phase currents, to the current coils of the H.T. meter, there is likely to be, in the respective supplies—

(1) a change in polarity only.

(2) a change in sequence only, or

(3) a change in both polarity and sequence.

Including the connection with correct sequence and polarity, there are, therefore, four possible methods of effecting current supply connections to the meter.

Similarly, with respect to the potential connections to the two meter coils, there is likely to be a phase rotation of 120 degrees either way, resulting in three methods of connections to the meter.

A combination of the different current and potential connections would give rise to a set of 12 possible connections to the meter, for all of which the meter would register in the forward direction and for not a few of them, the registration of the meter, under limited variation of load power factor, would agree closely with the energy supplied to the H.T. consumer.

Where there is definite suspicion in the meter connections on grounds of wide dispartiy, noticed between the computed energy supply, and the energy supply indicated by the H.T. meter, high line losses, too-good distribution efficiencies, etc., the current inter-change or the voltage inter-change test would enable the current connections being restored in the correct sequence, and polarity to the meter. The uncertainty in the voltage connections that would then remain can normally be resolved by the observation of continuation or otherwise of the deficiency, that gave rise to the suspicion of incorrect meter registration, a study of the behaviour of the meter under changes in load; study of behaviour on switching on or off particular types of load, etc. No great difficulty would arise in the choice of proper voltage connections, as a shift in meter power factor by as much as 60 degrees, that would result in consequence of an incorrect connection, to the potential coils of the meter, cannot escape notice for long.

It is possible for the meter connections to be incorrect; and to continue to be so, under certain conditions, without being noticed. It

is necessary that, in every case, inaccurate meter connections are rectified; and the metering made absolutely reliable. To what extent, an observation of the behaviour of the meter, under different load conditions, pertaining to the H.T. service, would enable the verification of the correctness or otherwise of the connections, and determination of the exact nature of inaccuracy, in case the connections are incorrect, is well worth investigation. Such a study is made in this article.

2. Meter registration versus incorrect connection.

General metering particulars.—In every H.T. meter, the following particulars are either, directly available, or can be generally found out by tests:—

(1) Registration of the meter, as a whole, and for each element,

(2) voltage at the meter terminals, and

(3) value of load current.

Registration of each element, may be found, by disconnection of the red phase and blue phase potential fuses, one after another, and noting the meter registration by a stop watch. If there is no voltmeter on the metering panel, the voltage at the meter can be read off, by a portable indicating meter; and where there is no ammeter with phase change-over switch, the load current can be determined by a tong test ammeter.

Computed meter registration.—With a knowledge of the approximate power factor of the load, it is possible to compute, from the voltage and the current values, what the meter registration should be. Where a number of L.T. meters are installed in the distribution, summation of L.T. units, with the requisite percentage correction for the line and transformer losses, would give closely what the H.T. meter registration should be. If the computed meter registration agrees with the observed figure, there is reasonable cause for satisfaction; and, if there is disagreement between the computed and observed registrations of the meter, it would be a strong pointer towards incorrect connections to the meter. But it has to be conceded that the meter connections may be incorrect; and the incorrectness gets masked by a fairly close registration. Feasibility of such an occurrence has to be studied.

Possible connections with close registration.—For the normal load power factor variation of 0·5 lag to unity, a study of all possible connections was made to see whether for any one of them, for any particular power factor, within this range, the meter registers the load correctly. Possible connections are listed in the table below:—

Meter connections.	*Meter registration. E.I.×.*	*Power factor.*
(1)	(2)	(3)
(BR, B) (YR, —R)	2 Sin (60 —θ)	Unity.
(YB, —B) (RB, —R)	2 Sin (60 +θ)	Unity.
(BR, —R) (YR, —B)	√3 Cos (60 —θ)	0·87 lag.
(RY, B) (BY, —R)	2 Sin θ	0.76 lag.
(RY, —R) (BY, B)	Sin θ	0·5 lag.
(YB R (RB, —B)	Sin 5 (60 +θ)	0.5 lag.

Column (1) in the table gives the meter connections, column (2) the function for meter registration; and column (3) the load power factor, at which, the meter registration agrees, with the load, correctly. For example, the connection (BR, B): (YR,—R) indicates that the connections to the red phase, and the blue phase potential coils, are respectively BR and YR; and the corresponding currents, given to the two elements, are B, and R reversed. The meter registration for this connection is given by the function 2 E.I. sin (60—A). At unity load power factor, the meter registers 2 E.I. sin 60° or $\sqrt{3}$ E.I. The actual load, however, is $\sqrt{3}$ E.I. Cos θ which at unity power factor is equal to $\sqrt{3}$ E.I. Hence at unity power factor, the meter, under this connection, registers the load correctly.

Too many possible connections.—It is seen from the table that there are as many as six connections, for which the meter registers the load correctly, between power factor unity and 0·5 lag. The particular power factors, at which the meter registration is correct, are seen to be unity, 0·87 lag, 0·76 lag and 0·5 lag. If the variation of the power factor of load is small, there is some connection, or other, at which the meter registration is fairly close to the actual energy consumption: and if the energy consumed, during low loads is, but, a small fraction of the total consumption, it is possible, that the disparity between the meter registration, and the actual energy consumption, is negligible and is unnoticed. Hence the actual meter registration, except in a few special cases, where the power factors of the load, under full load and low load conditions, are approximately known: and the power factor variation is distinctly wide; cannot be relied upon to the extent of affording requisite assistance to enable a correct decision, being arrived at, on the correctness or otherwise of the meter connections.

Insufficiency of registration check.—In any general case, it would probably be known, whether the power factor is lagging and between 0·5 and unity; about 0·5 lag, or less than 0·5 lag; but more exact information, would be wanting. Also, in cases of services, where, the summation of L.T. meter registrations, enable the H.T. supply units, being derived, inaccuracy in the data on distribution losses and errors in the L.T. meter registrations themselves, would vitiate the computation of H.T. energy supply. It is, therefore, generally desirable to decide the correctness of connections, without taking into consideration, any relationship between meter registration and load consumption.

3. Registration and meter element power factors.

Power factor from meter element speeds.—As the meter registration is a function of voltage, load current, and load power factor, a knowledge of power factor would enable the registration being calculated. Conversely, the load power factor, Cos θ, can be determined from a knowledge of registration, voltage and load current. Also the individual elements of a correctly connected meter,

register energy proportional to Cos $(30+\theta)$ and Cos $(30-\theta)$, respectively and the ratio of the registration of the two elements is Cos $(30+\theta)$ 1 Cos $(30-\theta)$. This, for a power factor variation, zero lag to unity varies from minus one to plus one. Thus there are two

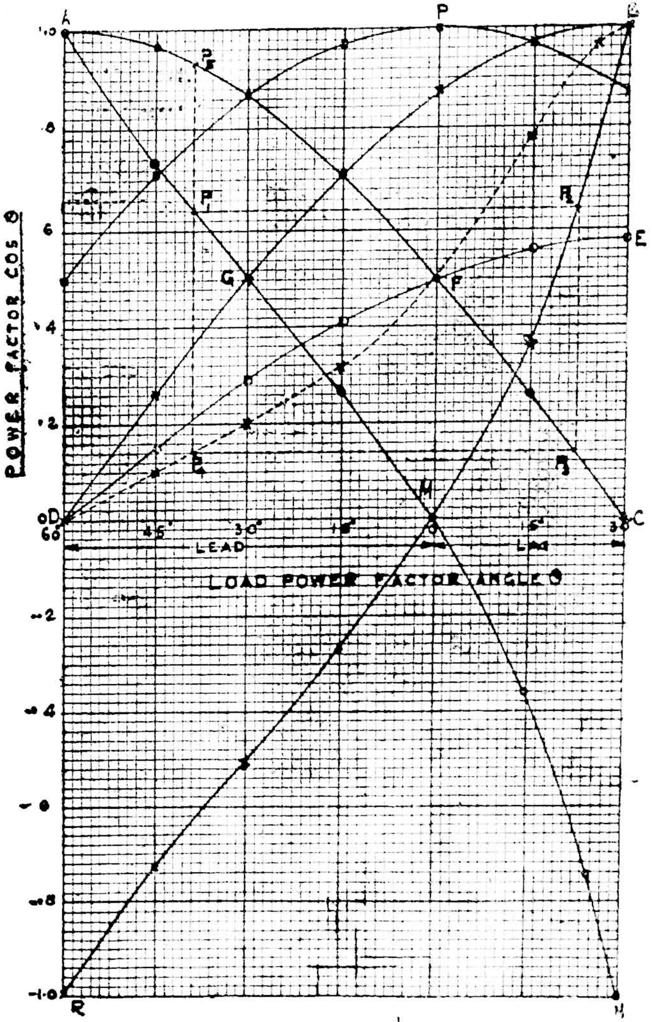


FIG. 1.

methods of determining the power factor:—

(1) From the meter registration, regarded as a function of voltage, and current, and

(2) from the ratio of registrations of the two elements of the meter; generally the slow element registration, divided by the fast element registration.

The former may be called the "registration power factor" and the latter, the "inter-element power factor".

Effect of incorrect connection.—If the current connections are given properly, with respect to polarity, and sequence, the registration power factor, and the inter-element power factor, would be identical, under all load conditions. Where, there has been a mistake, in giving the connections, the two would, obviously, have different values, except, probably, at certain particular common points.

Instance of meter registration with (YB, RB) connection.—The set of connections (YB,—R) (RB, —B) can be taken by way of illustration. The red and blue potential coils, are connected to YB, RB respectively. The red current coil is connected to 'R' current reversed, and blue current coil to 'B' current reversed. The current connections are given in correct sequence and polarity; and are therefore correct. The meter records $\sqrt{3}$ E.I. Cos (60+) for these connections. On effecting changes of polarity, and sequence of the two currents, the meter registrations, would be as under:—

Connections.	*Registrations.*
(1) 'R' current to Red current coil; 'B' reversed to Blue current coil.	EI Sin. $(60+\theta)$
(2) 'B' reversed to Red current coil; 'R' current to Blue current coil.	2 EI Sin. $(60+\theta)$

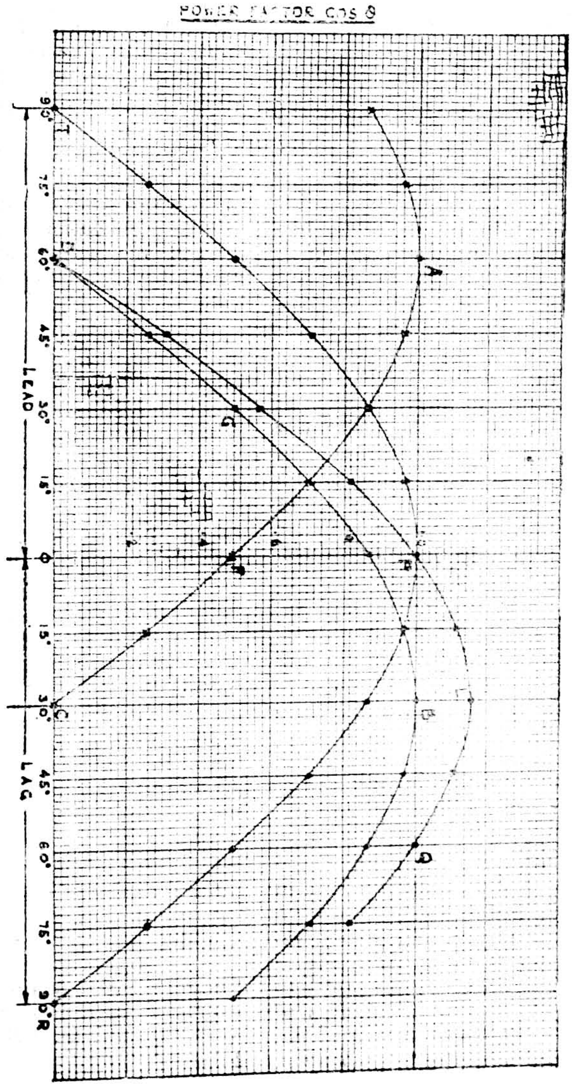
It is possible to effect a change of sequence of currents only, that is, with 'B' current to red current coil; and 'R' current to blue current coil; but here the meter does not register at all. As the complete stoppage of meter, under all power factor conditions of load is bound to draw one's attention thereon and the connection would be altered, one way or the other, this connection may be left out of consideration. Hence connections (1) and (2), indicated above, are, the only possible alternatives to be studied in detail.

4. Current connection with change of polarity and sequence.

Inter-element power factor.—For connection (2), including change of polarity and sequence of currents, the registration by each element is E.I. sin. $(60+\theta)$; and the ratio of registration of the two elements is therefore unity, indicating a power factor of unity. Under all conditions of load, the inter-element power factor is, therefore, unity, for all power factors.

Registration power factor.—The registration power factor is total registration divided by $\sqrt{3}$ E.I.

As the registration of the meter, here, is 2 E.I. sin $(60+\theta)$, the registration power factor is $(2/\sqrt{3})$ sin $(60+\theta)$.



POWER FACTOR ANGLE θ

FIG. 1

In Fig. 2, APQ indicates the inter-element: and DPL, the registration power factor. TPR is the load power factor curve, zero lead to zero lag. It is seen from the figure, that the maximum registration is $(2/\sqrt{3})$ or 1·15, when load power factor is 30 degrees lag, and that the registration power factor is greater than unity for a load power factor variation from unity to 0·5 lag.

Common values of power factor.—There are two common points, P and Q, on the inter-element and registration power factor curves corresponding to the load power factor of unity, and 0·5 lag. The registration and inter-element power factors are both unity at these points. When the load power factor varies to any figure, distinctly different from unity or 0·5 lag, the registration power factor and the inter-element power factor would give widely different values.

Variation at common points.—The table below gives the registration power factor for small variations of load power factor about unity and 0·5 lag.

Load power factor.	*Registration power factor.*
(1) 0·98 lead.	0·86
Unity.	1·00
0·98 lag.	1·09
(2) 0·6 lag.	1·06
0·5 lag.	1·00
0·4 lag.	0·92

Excepting for a small variation in load power factor, accounting for a variation of registration power factor of about 5 per cent on either side of unity, that is, from 0·95 to 1·05, at all other power factors of load, the difference between the registration and the inter-element power factors are quite distinct; and clearly indicate that the connections are given with a combined change of polarity and sequence. On noting down the registration and inter-element power factors of the meter, at different times, if there is continued indication of inter-element power factor, as unity; and the registration power factor, averaging unity, but actually varying from about 1·15 to unity or less, it is a sure indication that the current connections to the meter have been effected with a combined change of polarity and sequence.

Special features of the connection.—The special features, regarding the registration, and inter-element power factors, pertaining to connection (2) involving change of polarity, and sequence in the current connections are given below:—

(1) The inter-element power factor is unity for all load power factors.

(2) The registration power factor may exceed unity and may reach a maximum figure of 1·15.

5. Current connection with change of polarity only.

Registration of each element.—For connection (1), involving change of polarity of one current only, namely, red phase current, the registration of the two elements individually are as under:—

Meter elements.	*Registration.*
(1) Red element.	EI Sin θ
(2) Blue element.	EI Cos $(30+\theta)$
Total.	EI Sin $(60-\theta)$

The registration of the red element, expressed as ratio of the blue element registration is Sin θ / Cos $(30+\theta)$.

Inter-element power factor by calculation.—Under correct connections to the current coils, i.e., connection without any change of polarity or sequence, the registrations would be as under:—

Meter element.	*Registration.*
(1) Red element.	$\sin\theta$
(2) Blue element.	$\cos(30+\theta)$
Total.	$\sqrt{3}\cos(60-\theta)$

The ratio of registration of the red element, to the registration of the blue element would then be $-\sin\theta/\cos(30+\theta)$. On reversing the polarity of red current, to get at connection (1) the ratio of registration, simply charges sign.

Assuming that for the ratio $+\sin\theta/\cos(30+\theta)$, the corresponding load power factor is Cos γ, the ratio of registration for Cos α, would be $-\sin\alpha/\cos(30+\alpha)$. Hence, we have,

$$-\sin\alpha/\cos(30+\alpha) = \sin\theta/\cos(30+\theta)$$

which on simplification works out to

$$\tan(60+\alpha)\tan(60+\theta) = -3.$$

From the above relationship, the curve of inter-element power factor, that is, power factor, as indicated by the ratio of registrations of the two elements, can be plotted. The curve DGB in Fig. 1, indicates the inter-element power factor curve.

Inter-element power factor by graph.—The inter-element power factor can be derived graphically also as under:—

In Fig. 1, AFC is the curve: $Y=\cos(60+\theta)$: and represents to scale meter registration on variation of load power factor keeping current constant. The ratio of registrations of the two elements is given by the curve AMN: $Y = -\sin\theta/\cos(30+\theta)$.

For a point P_1 on the ratio curve AMN, the corresponding power factor indicated by the meter under correct current connections is given by P_3 on Cosine curve AFC.

In the same figure, curve PMB represents the negative ratio curve: $Y=\sin\theta/\cos(30+\theta)$.

Ratio represented by the point P_1 on the positive ratio curve, on the change of polarity of the red phase current, changes sign, and gets represented as a point P_2 on the negative ratio error curve.

The power factor corresponding to the point P_2 is given by point P, on the Cosine curve AFC.

In Fig. P_1, P_2, P_3, P_4 is a rectangle.

The power factor represented by P_3 and corresponding to the point P_1 on the ratio curve, gets presented due to change of sign of re relation, ship, on change of polarity of current, by the point P_4 Point P_3 gets therefore indicated as point P_4. Other points are plotted similarly, and the curve DFB obtained.

Registration power factor.—The registration of the meter, being EI $\sin(60+\theta)$, the registration power factor is $(1/\sqrt{3})\sin(60+\theta)$. The registration power factor curve is given by the curve DFE in Fig. 2. It is seen there are two points of inter-section D and F, between the two curves. The point D corresoponds to nil registration by meter and needs therefore no

consideration. The point F corresponds to nil registration by the red element of the meter; and a load power factor of unity.

Comparison of registration and inter-element power factors.—The extent of difference between the two power factors, for small variations, about the common points, would be useful. The table below gives the registration power factor for small variations of the inter-element power factor, about the common points; and also for a general variation of inter-element power factor from zero to unity.

Registration power factor.	*Inter-element power factor.*
0·16	0·1
0·30	0·2
0·40	0·3
0·46	0·4
0·50	0·5
0·52	0·6
0·54	0·7
0·56	0·8
0·57	0·9
0·58	1·0

If the registration and inter-element power factors both give 0·5 power factor, no decision on whether or not there is change of polarity in current connection can be arrived at. It would then be desirable to determine the registration and inter-element power factors, at some other time, when the two may be distinctly different from 0·5.

It is also to be noted that as the registration power factor is given by $(1/\sqrt{3})$ Sin $(60+\theta)$, its maximum value can be only $(1/\sqrt{3})$ or 0·58.

Special features of the connection.—The special features regarding the registration and inter-element power factors, pertaining to connection (1) involving change of polarity of one current only, are given below:—

(1) The inter-element power factor is not limited to unity alone. It may have any value plus one to minus one : the rate being taken as one of smaller, over the higher speed.

(2) The maximum registration power factor is $1/\sqrt{3}$ or 0·58 only.

General applicability.—The special features, mentioned as pertaining to the current connections, involving change of sequence and polarity, for the voltage connection (YB, RB) to the potential coils of the meter, are equally applicable to the voltage connection (BR, YR); and to the voltage connection (RY, BY) to the meter potential coils.

Similarly the special features mentioned, as pertaining to the current connections, involving change of polarity of one current, alone, for the voltage connection (YB, RB) to the potential coils of the meter, are equally applicable to the voltage connection (BR, YR), and the voltage connection (RY, BY) to the meter potential coils.

6. Summation of observations.

The observations made above on the meter under different conditions may be summed up as under:—

(1) Where the inter-element power factor is found to be unity, every time, when checked up, at suitable intervals, in the course of a day, and the registration power factor is, at some time, distinctly different from unity, there is good reason to believe that there is a change of sequence and polarity in the current connections.

(2) If the inter-element power factor is not unity at any time of check, it is definite that the current connections do not involve a combination of change of sequence and polarity.

(3) If the registration power factor, at any time, exceeds unity, and has some value, less than 1·15, it is definite that the current connections involve change of polarity and sequence.

(4) If the registration power factor is distinctly different, from the inter-element power factor, at any time, and the inter-element power factor is not unity, it is definite that the current connections involve change of polarity only.

(5) If the registration power factor and the inter-element power factor are identical every time, a check up is made, and have values neither equal to, or close to unity: or 0·5, one time or other, the current connections to the meter are correct.

It would be seen from the above, that by observing the registration power factor and the inter-element power factor, one time at full load, and another at low load, it would generally be possible to decide whether the current connections have been given correctly with proper sequence and polarity, to the H.T. meter.

7. Trivector meters.

Kilovarh meter registration.—In the majority of H.T. services, trivector meters are installed by the Department; as such meters have incorporated in them, a KWH meter: a KVARH meter a KW maximum demand indicator: and a KVA maximum demand indicator; and the consumer has, therefore, the option to choose either the KW or KVA maximum demand basis for the tariff, as would be to his benefit. Also the concurrent recording of the KWH and KVARH meters enables a close watch being maintained, on the overall load power factor, at the service.

It may, at first sight, be thought that, in the case of a trivector meter, the registration power factor and the inter-element power factor may be determined, from the registration of the reactive energy meter, as a whole, and the individual registrations of its elements: and their values compared with similar values obtained for the KWH meter. But on scrutiny, it would be clear that the values so determined would be identical with the values determined from KWH meter registrations and no comparison is therefore possible. But the ratio of registrations of the reactive energy meter, and the KWH meter is a distinct figure, that is likely to be of some assistance in determining the correctness of current connections.

Ratio of KWH to KVARH meter registration.—In the instance of the potential connections to the two elements, being (YB, RB), the KVARH meter registration for current connection involving—

(1) A change of polarity of current only, and

(2) a change of both polarity and sequence,

would in magnitude be as under:—

Connection.	*Registration—Value.*
(1) Recurrent to Red Current coil; 'B' reversed to Blue current coil.	EI Cos (60+θ).
(2) 'B' reversed to Red current coil; Recurrent to blue current coil.	2 EI Cos (60+θ)

On comparing the above registrations, with the registrations of the KWH meter, with similar connections, it is seen that the ratio KWH meter registration over KVARH meter registration is tan $(60+\theta)$ for both connections (1) and (2).

Vector power factor.—It is possible to derive one power factor from the ratio of registrations of the two meters; and the power factor, so derived, from the ratio, may be called the vector power factor.

For the correct connections (RY, R) (BY, B) to the KWH, and the KVARH meters, the KWH meter record is a function of Cos θ, and the KVARH meter record, a function of Sin θ; the ratio, KWH meter registration over KVARH meter registration is Cos θ; if this ratio is represented by r, the true power factor Cos θ is given by $r/\sqrt{1+r^2}$ The vector power factor is therefore $r/\sqrt{1+r^2}$

Applying this, to the instance, under consideration, as the registration of the KWH, and the KVARH meters for connections (1) and (2) is tan $(60+\theta)$ the vector power factor works out to sin $(60+\theta)$.

In Fig. 1 and Fig. 2, curve DGB represents Sin $(60+\theta)$

Comparison between three power factors.—In the case of trivector meter, therefore, it is possible to compare any two of the three power factors, viz., the registration power factor, inter-element power factor, and the vector power factor.

Comparison of the registration and inter-element power factors has already been considered. Comparison of the vector power factor with either the inter-element power factor or the registration power factor is considered below.

8. Vector power factor versus inter-element power factor.

Connection with change of polarity and sequence.—For connections 2 involving change of polarity and sequence, the inter-element power factor is unity for all variations of load power factor and is represented by AB in Fig. 2. DGB is the vector power factor curve. Therefore the only common point for the curve AB, and curve DGB is the point B, corresponding to an actual load power factor of 30 degrees lag.

Connection with change of polarity only.—For connection 1, involving change of polarity only, the inter-element power factor is DFB; and the only points common to both the curves are D and F. Of these, point D corresponds to zero registration and needs no consideration. Hence the only material point, that is common, is again F.

It is seen that excepting at the region of unity there is ample difference between the pair of inter-element power factor curves. Hence there should, normally, be

no difficulty, in deciding whether the connections are correct or not.

Special features of comparison.—The special features pertaining to the above comparison are given below:—

(1) For every vector power factor, distinctly different from unity, there is definite indication whether the connections are correct or not.

If the inter-element power factor is unity, the current connections involve change of polarity and sequence; and correct current connections can be restored by an inter-change of current connections to the meter; and also by a reversal of polarity of one current.

If the inter-element power factor is less than unity, and incidentally less than the vector power factor, itself, the current connections involve a change of polarity only; and correct connections can be restored by simply reversing polarity of one or other of the two currents.

(2) The comparison does not involve measurement of either the voltage or the current. It involves only the individual registrations of the two elements of the KWH meter and total registrations of the KWH and KVARH meters.

(3) When the inter-element and vector power factors are both unity or very nearly unity, it is not possible to come to any decisions on the correctness or otherwise of the current connections to the meter.

Importance of unity power factor indication.—It is of interest to note that the unity power factor indication, by both the inter-element and vector relationships, for the potential connections (RY, BY) to the meter, corresponds to a load power factor of 30 degrees lag, which is, probably about the average power factor under load, in most of the H.T. services. Therefore, there should, if possible, be no ambiguity, in deciding the correctness of connectors, when the inter-element power factor is unity. Comparison of the vector power factor with the registration power enables an unambiguous decision being arrived at, as explained below.

9. Vector power factor versus registration power factor.

Similarity of functions.—In Fig. 2, DGB is the vector power factor curve and DFE, the registration power factor curve, for the connection with one reversed polarity current; in Fig. 1, DFL is the registration power factor curve for the connection, involving change of polarity, and sequence of currents.

The functions of the three curves are—

$$Y = \text{Sin}\,(60 + \theta).$$

$$Y = \frac{1}{\sqrt{3}}\,\text{Sin}\,(60 + \theta).$$

$$Y = \frac{2}{\sqrt{3}}\,\text{Sin}\,(60 + \theta).$$

It is therefore clear that—

(1) the maximum value of the registration power factor for the current connection involving combined change of polarity and sequence is $2/\sqrt{3}$ or 1·15.

(2) The maximum value of the registration power factor, for the current connection involving change of polarity alone is $1/\sqrt{3}$ or 0·58.

(3) The ratio between the registration power factor and vector power factor is 1·15 for every value of load power factor for the connection, involving change of sequence and polarity.

(4) The ratio between the registration power factor and vector power factor is 0·58 for every value of load power factor, for the connection involving change of polarity alone.

Special features of the comparison.—Special features pertaining to the above comparison are as under:—

(1) The ratio between the registration power factor and the vector power factor, if not unity, is either 1·15 or 0·58 only; and none other. In the former case, there is indication of a change of sequence and polarity of connections; and the correct connections are restored, with an inter-change of current connections to the meter and also a reversal of polarity of one or other of the two currents. In the case of the latter, there is indication of a change of polarity only and correct connections, can be restored by a reversal of polarity of connection of one or other of the two currents.

(2) When the vector power factor is unity, and the inter-element power factor being also unity, makes a decision on the correctness of connections difficult, the registration power factor is observed to be 0·58 or 1·15 clearly indicating the nature of the existing current connection to the meter.

(3) When the vector power factor, and the inter-element power factor and registration power factor are all unity, the current connections to the meter are correct and require no change.

(4) When the vector power factor, the inter-element power factor and the registration power factor are, all same, but not unity, then also, the current connections are correct and require no change.

(5) As the use of registration by the meter, as a whole is more reliable in accuracy, than the individual registrations of its elements, the method of comparing the vector power factor with registration power factor is generally preferable to the one of comparing either of the above with the inter-element power factor.

Precaution.—It may be mentioned that, in arriving at the vector power factor, some care had got to be exercised. When the vector power factor is unity, the KWH meter would register and the KVARH meter would not. As normally there is a stop in the KVARH meter preventing backward rotation, it would be necessary to ensure, that the meter has really come to standstill due to the load condition and not due to the stop.

10. Conclusion.

There are innumerable tri-vector meters and KWH meters, installed to measure consumption in H.T. services, served by the Department. When the meters are initially installed, with potential and current transformers, and when the current or potential transformers are removed for overhaul or repairs, and re-installed later in the circuit, connections are carefully checked up, but despite

all carefulness exercised in attending to such work, an incorrect connection gets sometimes inadvertently given. As H.T. services serve important loads, it is necessary that chances of incorrect connection are totally avoided, and also an overall check is carried out, on initial commissioning of the metering set; and every time, the set is recommissioned after repairs. The current interchange or voltage interchange test provides such an overall check on the connections and enables the testing engineer to ensure that the connections are given in correct sequence and polarity. Observation of the inter-element power factor, the registration power factor, and the vector power factor, where possible, of the meter involves no disconnection of meter, and no interruption to supply. Thus determination and study of their mutual relationships will be found very useful by the engineer-in-charge in ensuring that the connections to the meter continue to be correct, and incidentally there is no internal discontinuity within the meter itself. Where the engineer-in-charge or the inspecting officer feels there is distinct feasibility of an incorrect connection, on the basis of any particular behaviour noticed, of the meter, under changes of load or other observations, made, that cannot otherwise be accounted for, the three point information, as regards the inter-element, registration and vector power factors, would enable the right decision being reached on the correctness or otherwise of the meter connections.

Suspicions on metering connections have generally been set right by a thorough check of polarity and sequence of connections to the meter, during shut-downs. A thorough check-up has definite value, but a check-up during shut-down has often a few limitations; and the testing engineer would still need to be satisfied that the meter functions satisfactorily, in service. The three-point check of the meter, in service, enables the testing engineer to infer and to ensure that the functioning of the H.T. meter is quite satisfactory.

Retirement of Sri Karantha—Editor

Sri K. V. Karantha was Editor of the Electricity Department Journal from June 1946 to April 1955. His services to the journal were invaluable. The Editorial Committee, in its meeting on 4th June 1956 passed the following resolution acknowledging the services rendered by Sri Karantha as Editor to the Journal during this long period.

" Sri K. V. Karantha, as Chief Electrical Inspector to Government, became Editor of the Electricity Department Journal on 18th June 1946, and he continued to shoulder the Editorial responsibilities till 27th April 1955, the date on which he took leave preparatory to retirement. During this long period of nine years, he took keen and personal interest in the improvement of the journal both in its outlook and in its contents; in examining and editing the technical articles from the Departmental staff; inclusion of important technical extracts from other journals and magazines; and preparation and presentation of " general notes by Editor ", a feature containing valuable suggestions and discussions on matters of general and technical importance. Sri Karantha himself contributed a number of useful articles to the journal. It is largely due to his personal interest in this journal that it has become ' a useful handbook of reference ' to the technical staff of the Electricity Department and has come to occupy a position of importance that it does to-day.

This Committee wishes to place on record its deep sense of appreciation of the long and devoted service Sri Karantha has done to the journal and wishes him complete happiness in his retirement."

T. KRISHNASWAMY,

Editor.

...NNIMARA PUBLIC ...
2 8 OCT 1956

Progress During the Quarter ending 30th June 1955

Salient features.

The operation and maintenance of all the systems was satisfactory.

The inflow into all the reservoirs during the quarter was very good and the storage position at the end of the quarter quite satisfactory.

The Department earned a revenue of Rs. 163·85 lakhs during the quarter. The working expenses amounted to Rs. 87·62 lakhs and the capital expenditure during the period was Rs. 69·91 lakhs.

Supply was given to 1,261 agricultural pumpsets, 185 industrial and 6,095 domestic services.

Eighty-five new villages were electrified during the quarter. Also 101 miles of H.T. and 226 miles of L.T. lines were constructed and energised.

Construction Branch.

Pykara Plant Extensions III Stage.—Masonry work in the main dam was continued and work in the spillway section, the spillway gates and on the earthbund was in progress.

The road and the bridge works of the re-aligned Mukurthi bridge were nearing completion.

Madras Plant Extensions.—The air conditioning plant under the first stage extensions was commissioned during the quarter.

Twenty per cent of the dismantling of the steel work and concrete foundations under the third stage was completed.

Orders have been placed by the Director-General, Supplies and Disposals, Government of India, for the boilers, turboset and switchgear for the third stage extensions

Periyar Hydro-Electric Scheme.—Acquisition of land for lower camp and formation of roads to upper and lower camps, power house, surge shaft and exit point of power tunnel were under various stages of progress. Construction of staff quarters in lower camp, buildings in upper camp and a 40-ton magazine was progressing.

Enlargement of tunnels for a distance of 1,000 feet from exit and 200 feet from the central shaft towards the exit was completed. Drilling of the power tunnel was commenced.

Excavation for forebay dam, penstock grading, and levelling of site of power house and transformer yard were in progress.

Salem-Namakkal 110 *KV line.*—The construction of the transmission line was practically completed during the quarter.

Singarappet-Villupuram 110 *KV line.*—Check survey, excavation of pits, stub setting, concreting and tower erection were under various stages of progress.

Singarappet-Vellore 66 *KV line.*—Check survey, tree clearance, excavation of pits, stub setting and concreting were under various stages of progress.

South Kanara Scheme—Hulikal-Mangalore 110 *KV line.*—All the line works were almost completed.

Udipi-Hiriadka-Karkala 33 *KV line.*—All the line works were completed.

Udipi-Coondapur 33 *KV line.*—Pegging out pole location, erection and earthing of poles, stringing of power and telephone conductors were under various stages of progress.

Sub-stations.—Construction of staff quarters for the sub-stations were under various stages of progress.

Structure works were completed at Mangalore, Coondapur and Udipi sub-stations and were in progress at Hiriadka and Karkal.

Neiveli-Villupuram 110 *KV line.*—Route plan was prepared and submitted to P.T.C.C. for approval.

Villupuram-Pondicherry 66 *KV line.*—Reconnaisance was completed and theodolite alignment was in progress.

Periyar Transmission lines—Theni-Sembatti 110 *KV line.*—Preliminary survey of the line was in progress.

Periyar-Theni-Madurai 110 *KV line, Sembatti-Tiruchirappalli* 110 *KV line and Sembatti-Karur* 66 *KV line.*—The routes were reconnoitered and plans were prepared.

Madukkarai-Palghat 66 *KV line.*—Approval of the P.T.C.C. was obtained for the proposed route. The sites for the sub-stations were examined and acquisition proposals forwarded to the Revenue authorities.

Operating Systems.

Hydro Systems.

Generation.—The station peak loads, the system peak loads and units generated were as follows:—

Name of System/Station.	Station peak load in M W	Units generated in millions.	System peak load in M W
Pykara	68·40	88·6646 }	59·9
Moyar	36·00	37·8694 }	
Mettur	37·00	40·3638	62·6
Papanasam	28·00	31·9587 }	26·6
Madurai (thermal station) ..	10·80	6·2606 }	
Udipi	0·285	0·1950	0·29
Karkala	44·5 KVA	0·0190	0·05

The inflows into all the reservoirs during the quarter was very good due to the summer showers in April and May and a spell of monsoon in June. The storage position in all the reservoirs in consequence was quite satisfactory.

The improvement in the water position in the hydro areas enabled the Madurai Thermal station which was giving relief during April 1955 being shut down from 4th May 1955. Import from Madras was also stopped on 8th May 1955 and

export of maximum power commenced from 18th May 1955.

The important works attended to during the quarter are given below:—

(1) The annual overhaul of the boiler No. 1 at Madurai Thermal station was carried out and the boiler inspected by the Inspector of Boilers.

(2) At Mettur the annual overhaul on No. 4 machine was carried out and the emergency hoisting gear of No. 3 machine was overhauled and commissioned.

The following services were connected during the quarter:—

System.	Agricultural.	Industrial.	Domestic.
Pykara ..	**562**	**47**	**1630**
Mettur ..	**371**	**29**	**910**
Papanasam	**188**	**28**	**2398**

The following were the more important works attended to during the quarter:—

Pykara System.—The Somanur Puliampatti 66 KV line was nearing completion.

In the Cannanore-Badagara-Quilandy 33 KV extension 400 poles were erected and conductors strung for 270 spans.

The Ingur-Olapalayam 33 KV extensions were in progress.

Metering sets were erected at Periyar project and Vaigai reservoir project and commissioned.

Mettur System.—The total out-turn of Mettur workshop during the quarter was Rs. 6·62 lakhs.

The permanent 66 KV sub-station at Kumbakonam with two 1,250 KVA transformers was commissioned.

Supply to Krishnagiri project was given.

Papanasam System.– The Thalayuthu 66 KV sub-station was commissioned with two 3,000 KVA transformers and one 2,000 KVA transformer.

The temporary Melakallur 66 KV sub-station was commissioned with a 500 KVA transformer.

Thermal System.

Madras System.—The station peak load, system peak load and units generated were as follows:—

Name of station.	Station peak load in M W	Units generated in millions.	System peak load in M W
'A' Station	19·8	19·155	
'B' Station	22·6	25·645	35·10
'C' Station	2·3	0·071	

One hundred and forty agricultural services, 81 industrial services and 1,157 domestic services were connected during the quarter. D.C. services totalling 528 were changed over to A.C. Laying of 11 KV cables for the ring main in the city was in various stages of progress.

At "B" station the overhaul of boiler No. 3 was completed and the boiler put on range. The turboset

No. 1 commissioned in January under II stage extension developed heavy vibration and the H.P. shaft was sent to the company's works in U.K. for rectification.

The "C" station was dismantled and the dismantled parts despatched to Neiveli.

Rural Electrification.—The number of villages electrified during the period under review in the various systems was as follows:—

System.	
Pykara	30
Mettur	22
Papanasam	22
Madras	16
Total ..	90

A large number of rural extensions was progressing. The lengths of lines constructed and brought into beneficial use during the quarter are given below:—

System.	Length of lines H. T. in miles.	Length of lines L. T. in miles.
Pykara	16·29	40·78
Mettur	33·49	65·52
Papanasam ..	36·85	89·07
Madras	14·01	31·22
Total ..	100·64	226·59

Accounts Branch.

The Department earned a revenue of Rs. 163·85 lakhs during the quarter and the working expenses including suspense amounted to Rs. 87·62 lakhs. The capital expenditure during the period under review was Rs. 69·91 lakhs.

The following voluntary loan contributions towards capital works were received in the various systems to the end of June 1955:—

System.	Rs. in lakhs.
Pykara	10·91
Mettur	3·85
Papanasam	2·94
Madras	18·90
Total ..	36·60

Technical Branch.

(*a*) *Electrical.*—The following were some of the more important works attended to during the quarter:—

Tenders received for the Periyar power house transformers and transmission lines coming under the scheme were analysed and orders placed.

Specification for supply of materials and erection of 110/66 KV line from Udumalpet to T.C. State border; One 100 tons per hour coal crusher for Madras III Stage extensions; distribution transformers and lines and service materials required for Rural Electrification Programme; and additional machineries required for Mettur workshops were prepared and issued. Tenders received for the supply of cables and cable boxes for Madras System were analysed and orders placed.

The specification for the purchase of two 275 KW diesel electric sets and two 400 HP pumpsets sent by the General Superintendent, Lignite Investigations, Neiveli, were scrutinized.

Purchase orders for spares worth Rs. 6·1 lakhs were issued during the quarter. Materials required for Rural Electrification Programme were ordered at an estimated cost of Rs. 158 lakhs.

(*b*) *Civil Branch.*—The following were some of the more important works attended to during the quarter:—

Foundation drawings for a number of sub-stations were prepared.

Specifications were issued for the supply of cranes and supply and erection of structural steel work for Periyar Power House.

The offers received for the power tunnel work of the Periyar Hydro-Electric Scheme were analysed and the contract awarded.

Preliminary reports for Mettur low level hydro-electric scheme and Kumbar Amaravathy hydro-electric scheme were prepared.

Collection and compilation of rainfall and run-off figures of the various basins and rainfall figures obtained from other departments and private estates were continued. The number of rainfall stations rose from 464 to 483 to the end of the quarter.

General.—The draft Second Five-Year Plan at an estimated cost of Rs. 74·38 crores for power schemes were prepared and submitted to Government.

Technical Press

Electrical Energy from the Wind.

Because of the demand for the benefits of electricity supply in remote areas, where there is little prospect of receiving mains supply, considerable interest has been taken for many years in the development of wind driven generators operating with a battery for storage to cater for calm spells. In spite of the fickleness of the wind as a source of power interest in generation by this agency has been maintained and considerable development work has been going on both in Great Britain and Overseas, and schemes envisaging much larger power units are now in hand.

In a paper read before the Institution of Electrical Engineers, Savoy Place, London, Mr. E. W. Golding, M.SC., TECH., M.I.E.E., Head of the Rural Electrification and Wind Power Department of the British Electrical and Allied Industries Research Association, No. 15, Savoy street, London, gave a comprehensive survey of all aspects of wind power generation. He said that the resurgence of interest in wind power generation is due to a number of causes. Among these are the costs of fuels and their high rate of exhaustion in some countries, the need for alternative sources of energy in countries, where the end of the exploitation of economic water-power sources is in sight, the desire for independence of imported fuels and the urge to make fuller use of some of the under-developed areas of the world, where a mains supply of electricity would be out of the question in the early stages of development.

Three scales in the possible use of wind power can be recognized: (*a*) small scale, by 0·5 to 10 KW sets, for isolated single premises, (*b*) medium scale, by 10 to 100 KW. plants, for communities which cannot otherwise be supplied economically, and (*c*) large scale, by generators, having a unit capacity of up to 1,500 KW. or more, used as fuel savers through the energy fed by them into a mains network.

After tracing briefly, the history of the use of wind power the paper dealt, in some detail, with the characteristics of wind power, the choice of sites and output considerations.

Wind-driven Machines.—Many types of windmill for driving electrical generators have been invented but they all fall into one of two main classes, namely, (*a*) the solid type, with the effective surfaces of the rotor, moving in the direction of the wind, (*b*) the propeller (or wind-wheel) type, with the rotor rotating in a plane perpendicular to the wind. The solid type is so called because they interpose continuously, in the path of the wind, active rotor surfaces which almost fill the cross-sectional area of the

column of air acted on—as distinct from the propeller type, in which only a fraction of the swept area is occupied by rotor surface. A cup anemometer is a simple example.

Since the active surfaces must always run at a speed lower than that of the wind, the rotational speed—which falls with increasing rotor diameter—is low so that expensive gearing is needed if a high-speed electrical generator is to be driven. This type is not, therefore, a promising type for electrical purposes of any appreciable scale.

In the propeller type of windmill the blades revolve at much higher speeds than do the solid type. The rotational speed increases as the number of blades is reduced. Two or three blades are used for the high-speed machines, generating electricity. When a wind rotor drives an a.c. generator connected to a constant-frequency network, it must run at constant speed. Optimum power coefficient can only be maintained (approximately) by variation of the blade pitch, but the cost of control-gear needed to vary the pitch with a continually-varying wind speed is probably not justifiable. It may be better to accept the small reduction of power from this cause, over the operating range of wind speed, and to use pitch changing—if at all—to control the power output for wind speeds above the rated value.

Features of Recent Designs.—In Table I the main features of several designs for large or medium-scale aero-generators of the propeller type are compared. The design capacities range from 45 to 7,500 KW. (with twin rotors) for rotor diameters of 43 to 225 feet and rated wind speeds of 24·6 to 35 m.p.h. There is agreement on the number of blades as 2 or 3, and variation of blade pitch is used in most designs. The S.E.A.S. machine has braced blades with fixed pitch except that the outermost portion of the blade can rotate through 45 per cent, under spring control, so acting as an air brake. Thomas' design with twin rotors also has fixed-pitch braced blades, and the rotors, running at variable speed, drive a d.c. generator feeding its output into a convertor.

The generators are most commonly of the induction type, which is robust and is stable in automatic operation, although Putnam used a synchronous generator for the Granpa's nob air-generator, and this type is used also in the Enfield machine.

Another possibility is an a.c. commutator generator running at variable speed yet supplying constant frequency.

Except in very small fast-running machines, the high rotational speed needed for the generator is attained through gearing. There is usually a gearbox aloft in the nacelle which houses the generator, but some medium-sized machines—such as the Danish Lykkergaard windmills—have a vertical driving shaft running down inside the tower with bevel gears at top and bottom. Alternatives to gearing, which is expensive and may prove a limiting factor in the construction of very large machines, have been

proposed. Some large German designs show two contra-rotating propellers, one carrying the rotor of an alternator and the other its stator, but such a scheme would appear to introduce difficulties in operating with an economically short air-gap.

In the Andreau principle of pneumatic power transmission, air is thrown out centrifugally from the blade tips, and the depression created drives an air turbine at the base of the supporting tubular structure. Power losses must be incurred in the double conversion of energy from aero-dynamic to mechanical form, at the top and bottom, there are advantages in having the machinery at ground level and in the lack of any specific relationships needed between the speed of the rotor, the generator and the wind, rapid changes in torque due to gusts may be damped out

Research and Development.—For the successful exploitations of wind power it is necessary to: (*a*) find windy sites, (*b*) make an aero-generator to operate satisfactorily, (*c*) test the performance of the machine, (*d*) study the methods of loading to ensure that the available wind energy is fully utilized.

The extensive E.R.A. wind power research programmes have been based upon these four requirements.

In all, more than 100 measuring sites in Great Britain have been used. These sites have been chosen mainly on the summits of well-exposed smoothly-shaped hills without precipitous faces and with no trees or other obstructions to disturb the wind-flow over them.

The construction and operation with an a.c. network, of wind-power plants of significant size lay outside the normal scope of E.R.A. researches. This part of the work was undertaken by the North of Scotland Hydro Electric Board, and the British Electricity Authority (now Central Electricity Authority), Trafalgar Buildings, London, both placed orders for 100 KW wind-driven generators and these are now undergoing trials. These are of different types with 3-blade rotors and automatic pitch control by hydraulic system.

A windmill-testing station has been established at Cranfield, Bedfordshire, close to the College of Aeronautics. Here a number of small windmills of different types up to 10 KW capacity are being tested in the same wind regime, and a series of investigations will be made to test the effects of artificially-created, irregular conditions of operation. The object is to provide information for aero-generator designers and to test the possibilities of a very simple and cheap construction.

Also at the Cranfield station, in conjunction with tests on small windmills in normal operation at remote premises, studies are being made of the methods of loading best suited to the fullest utilization of the annual energy becoming available.

The Economy of Wind-Power Utilization.—The cost of energy

production by wind-power is governed by the annual charges for interest, depreciation and maintenance of the plant, on one hand, and by the annual energy output on the other. The economy can be judged by a comparison of this cost with that of alternating means of energy production. Where electrical energy is cheap, large wind-driven machines must be located at sites with high mean wind-speeds if they are to be competitive, but where generating costs are high, smaller machines and lower wind-speeds may prove economically practicable. Thus the question of economy is relative rather than absolute. It is closely connected, also, with the cost of providing storage to cover calm spells. Storage of energy by a battery, or by any other means involving the provision of equipment which serves no other purpose, is expensive, and, even when used in only a limited degree, may double or treble the cost of the energy supplied to the load.

Under most circumstances, however, it is important that every kilowatt-hour of energy generated by the wind-power plant shall be utilized. This calls for its acceptance at the random times of its occurrence, and if storage is essential it should be by means of loads having inherent storage so that no great additional costs are involved in affording it.

Utilisation Factors.—Small wind-driven generators, of perhaps 1 or 2 KW capacity, are usually d.c. machines of low voltage—often not more than 32 V—and are provided with battery storage to cover calm spells of a few days' duration. Because of the low voltage, they must be located close to the premises to be supplied so that there is not free choice of site to obtain optimum wind conditions. The specific output, even in windly districts may not, therefore, exceed 1,250 KWH/year/KW.

A representative cost, with battery, is £200 per KW, while annual capital charges, enhanced may be 15 per cent. This leads to an energy cost of the order of 6 d. by the short life of the battery, per KWH, assuming that the machine is operated to make full effective use of the energy generated; probably, in practice, a figure of about 9d. per KWH would be realistic. This cost is high, but, for lighting purposes in a remote district, may not be considered excessive.

A study is being made of the possibilities of using such small machines, without a battery, for the sole purpose of water heating. Matching of the generator and load characteristics is then important, but the advantage may be that the need for a battery is eliminated.

The scope for wind-driven generators in the capacity range 10–100 KW is very varied.

There are, as yet, no firm cost data on which to base estimates of the costs of medium-scale plant in general, but evidence from Germany and Denmark on cost for the lower end of the capacity range indicates £120 per kilowatt (without battery storage) as a reasonable figure. Taking 12 per

cent annual charges and a specific output of 2,500 KWH/year/KW, the generating cost, for random energy, would be 1·4 d. per kilowatt-hour.

Approximate weights and dimensions for wind-driven generators at the upper and lower limits of this range of capacity are given in the table below:—

Machine.	*Capacity.*	*Diameter of blade circle.*	*Tower height.*	*Total weight.*
	KW.	FT.	FT.	TONS.
Conventional type (*a*) ..	10	20	45	1·1*
	100	50	80	20
Conventional type (*b*) ..	8	33	33	1·4
Andreau type	10	28	61	2·8
	100	80	100	40·5

* Without the tower.

The output of medium sized machines can be utilized in many ways than by battery storage such as electrolytic loading producing hydrogen gas for subsequent use, water pumping, or thermal storage in the form of heat. There may be scope for the hydrogen-oxygen fuel cell as a means of storing wind generated energy if a practical and economic form of cell results from researches on the subject.

Large wind-driven a.c. generators used in connection with main networks have the function of fuel savers. Up to the limit of the minimum power demand on the system—a limit high enough to provide ample scope for wind-power development—the output can be fed direct into the network to be used without any question of storage. Clearly the cost per kilowatt-hour of the energy so generated must not exceed the fuel component of generating cost by steam. At present this is about 0·41 d. per kilowatt-hour in Great Britain.

It is perhaps worth noting that wind-power might be combined very satisfactorily with hydro-electric power. The annual energy output from 500 KW of wind-power plant located at a site where the specific output is 4,000 KWH/year/KW would be equivalent to the potential energy of some 200 million cubic feet of water at 400 ft. head. If adequate water storage were available, some firm power value might be allotted to the wind-power through the additional hydro-electric generating capacity which might then be installed justifiably.

Conclusion.—The author concluded by saying that there is much to be done before wind-power will be able to take its full share in the world's annual production of energy, but he and his associates in this work do not see insuperable difficulties in the way. In their view, also, the contribution which wind-power could make to power production, while certainly limited,

is much greater than has been suggested recently by those who discuss it as merely an interesting possibility.

"*Electrical Industries Export*" May 1955.

Electric Power from Liquid Atomic Fuel.

American scientists to-day disclosed details of a new breeder re-actor which produces cheap electric power by using liquid atomic fuel.

It is unique among the systems being developed in the United States because the fuel is in the form of a solution of uranium in water.

The reactor will produce its own fuel if thorium—another type of fuel—is also present in the reactor. The amount of fuel originally present in the reactor is doubled in 1,500 days (about four years) of full operation.

A second experimental power reactor is under construction. Experiments have already reached a stage where it is possible to design a nuclear power plant to produce 100,000 Kilowatts of electricity—more powerful than the plant now under construction at Calden Hall assembled in Britain.

The American report said it was estimated that a 100,000 Kilowatt plant could be built within the next few years for between 20 and 25 million dollars. This compares with a cost of about 15 million dollars for a comparable coalfired plant.

The system which scientists and engineers at Brookhaven have been planning for several years would generate electric power, breed new fuels for itself and deliver by-products to waste tanks all in continuous processes.

A liquid metal alloy, a uranium-bismuth solution would be the fuel used, the scientists said.

"*The Hindu*", August 14, 1955.

New Fuse Elements.

A new NH fuse element has been developed to meet the requirements of modern heavy-current installations. It consists of a wide strip of electrolytic copper the "response zone" of which is coated with a high-fusing metal coating and provided with many contractions of the cross section so that both the thermal conductivity and porosity of the arc-quenching material in which the element is embedded are fully utilized. The thermal performance and the over-current carrying capacity and response delay of the element are controlled by the metal coating, the arc-quenching effect being improved by the multiple-break principle realized by the many contractions of the link. This design also prevents the occurrence of dangerous switching surges during transient processes.

"*Electrical Review,*" March 18, 1955.

Compound for Preventing the Seizing of Screw Threads.

A Product recently introduced in this country to alleviate the problem of seizing and galling of threaded connections subjected to

prolonged exposure to extreme heat is "Thread Gard," a special compound which, when painted on the surface of the bolt or stud before being fitted, is said to protect the thread against this welding action. This compound, which is manufactured by Grane Packing, Limited, of Slough, Bucks, lubricates and protects the threaded surface of studs, bolts, plugs, etc., and it is claimed that it is non-hardening and does not drip off after application. Further, it is said that wrench torque to produce a given tightness is reduced or alternatively fittings can be safely drawn up to a greater degree of tightness. Seizing and galling is prevented at operating temperatures up to 12,000 deg. F. yet threaded connections can be easily dis-assembled, it is claimed. Other applications for "Thread-Gard" include protection for thread cutting dies and taps, broaching and spinning tools, wire drawing dies, lathe centres, steady rests, rock drill pipe and bit threads. The manufacturers state that the anti-seizing and lubricating nature of the compound are attributable to the properties of its ingredients, combined with the precise technique of their blending. The underlying principle is the formation of a low sheer strength metallic film upon the associated surfaces, based upon the constituent element molybdenum disulphide. This metallic constituent when assisted by combination with other ingredients does in effect "plate" the surfaces during the action of their contact, and the greater the specific loading the more pronounced is the affinity of attachment and consequent lowering of the coefficient of friction.

Wooden Pole Conductivity.

Although there is a large amount of literature on most aspects of the use of wood for transmission and distribution line supports, particularly on the impregnation and protection of wooden poles against decay and pests, very little attention is devoted to the dielectric properties of wood and the danger of their deterioration, particularly under the effect of modern impregnating methods. These dangers are very real, quite a number of fatal accidents having been reported from various Continental countries, nearly always in connection with h.v. or l.v. lines on wooden poles impregnated with metal salts instead of creosote.

Measurements of the insulation resistance or conductivity of various kinds of timber have been carried out, but they do not enable any results of general validity to be obtained, since great variations of wood structure, age, seasoning, etc., must be taken into account even before the protective coating and impregnation have been applied. Accordingly, the *total* insulation resistance of a wooden pole may vary between 100 megohms and 400 ohms, or even between wider limits. The main influence accounting for differences of this order is the moisture content of the wood, but the fact that tar-oil impregnation is electrically safer than metal-salt impregnation is indisputable. These facts should

also be considered in carrying out repair and maintenance work on live lines on wooden poles, and even in felling trees along overhead lines since serious accidents have been due to trees making contact with live lines while workers were holding them—"The Problem of the Electrical Conductivity of Wooden Poles," G. Irresberger, E.T.Z. (B.), Vol. 6, No. II, pp. 407–409, 21st November, 1954, in German.

"*Electrical Review*", March 18, 1955.

The Electrical Property of Concrete.

The resistivity of concretes may be increased by special treatment. A typical application has been mentioned by Lambert and Ferrier, who describe the properties of a specially prepared concrete used for making third-rail insulators on French electric railways. The concrete was made with high-alumina cement, sand and gravel and gauged with water containing a bituminous emulsion. After hardening, the concrete was subjected to thermal treatment and finally varnished. It is claimed that such a concrete has a high resistivity of 1 × 10 megohm-centimetre, which compares well with the values for the oven-dried concretes. The dielectric strength of the special concrete is quoted as 10 KV *per centimetre*.

Immediately after prolonged immersion in water and while the insulators were dripping wet, the flash-over value was about 28 KV and its resistance was approximately 20 megohms, whilst both values rapidly increased on standing. The operating voltages of the lines in which the insulators were incorporated were below 1 KV in the instances cited. This special concrete, incorporating high-alumina cement, has also been used for casting *in toto* cap-and-pin insulators for use on 500 V lines. The neat cement is also employed in the manufacture of the normal glass and porcelain cap-and-pin insulators used on high voltage lines.

"*The Engineer*", January 28, 1955.

Roof Coating said to cut inside Temperatures 20 Deg.

Siliconed Asbestolite is an aluminium coating that is reported to protect and preserve roofs while reducing under-roof temperatures as much as 20 deg. The coating is composed basically of asphalt, asbestos and water roofing oils to which has been added silicones and aluminum flakes.

In addition to heat-insulating qualities, Asbestolite is said to shield buildings against cold. By holding roof temperatures more nearly constant with those of building interiors, it is claimed to reduce condensation by 60 to 70 per cent. Consequently, it is said to be suited for application over concrete block walls.

The compound comes mixed and ready to use in 5-gal cans and 30 and 55 gal drums. It does not require heating or thinning and can be sprayed on or applied with

a roofing brush or squeegee. It is said to be suitable for use on all types of roofs and reportedly can be applied over old coating without bleeding.

" *Engineering News-Record.*"
April 1955.

Central Control sends Signals over existing Wires.

A central control system has been designed that follows present programs and automatically switches on or off up to 40 groups of remote operations—each on its own time schedule.

Described as an "electronic supervisor", the new system provides economical remote control of facilities such as lights, air-conditioning and valves within a plant or building.

By superimposing electronic pulses of from 2,106 to 19,000 cycles on the electrical distribution system, the same lines which provide 60 cycle current for operation of numerous electrical devices can be used to transmit remote control signals. Thus, the electrical current which causes a motor to turn, or a valve to open, carries with it its own start and stop commands. These commands, originating in a flexible central operations panel, may be programmed automatically on a schedule designed to provide optimum efficiency in the operation of electrical facilities.

Another feature of the system is that time recording and time indicating equipment, including secondary wall clocks, may be automatically synchronized with a radio controlled master clock supervised by the National Bureau of Standards radio time signals.

" *Engineering News-record,*"
April 1955.

Photography speeds Triangulation.

Now available in this country is a theodolite that frees the instrument man from virtually all responsibilities except levelling and sighting.

Designed for first order triangulation, the instrument employs photographic registration of horizontal and vertical readings. Thus the operator is relieved of the work of continuous reading and can concentrate completely on sighting the target and centering the altitude index level. The film is exposed in a fraction of a second and moves automatically for a new reading—48 exposures are made on a standard roll of 35 mm film.

When the film is exposed, four things are recorded: the image of the horizontal and vertical circle; the reading of the plate level, free from any parallax error, at the exact moment of observation; the face of a clock to indicate the time —within seconds—of the observation; and notes made by the observer indicating such things as the date, location and his name.

According to the manufacturer, triangulation with the aid of photographic registration not only saves valuable time but also increases the accuracy of observation. The reason for this is that the influence firm external sources, such as

variations in atmospheric temperature, is minimized because of the considerably shortened period of measuring.

The theodolite is produced by Askania-Verke, A.G. in the American sector of Berlin. American representatives are the Geo-optic Co., New York.

"*Engineering News-Record*"
April 1955.

Dredge Hydro-quebec is floating Power Plant.

The world's most powerful dredge, the Hydro-Quebec, has also to be a most rugged piece of construction equipment. It must meet severe conditions of mechanical shock, vibration, torque, adverse atmosphere, dynamic overloads. And it must meet these requirements with power to spare, with fine control and with low maintenance cost.

This water-borne combination of mechanical and hydraulic excavator and transporter has three continuously operating main functions: the pump, the cutter, and the swing winch. All three are powered and controlled electrically.

The 17 feet diameter pump has passed boulders up to 30 inches across weighing about 1,500 lb. It passes these in less than half a second. This pump has an 8,000 h.p. motor with no-load speed of 257 r.p.m. on 13,200 volts, 3 phase, 60-cycle power.

To handle this type of load, the pump motor design provided for:

Class B insulation throughout.

200 per cent breakdown torque.

Continuous operation down to 80 per cent of rated speed at constant torque.

Lubrication under conditions of 8 deg. tilt fore and aft and 5 deg. tilt athwartship.

Special moisture resistant varnish treatment of rotor windings. Protective equipment on the pump motor includes:

Bearing temperature relays.

Resistance temperature detectors.

Drip cover.

Corrosion resistant fittings.

The speed, under-load, of the pump motor is controlled by a liquid rheostat load regulator which controls the motor secondary resistance. This speed control is essential to permit the dredge operator to select optimum speed to meet the varying conditions of density, suction head, discharge head, discharge line length and discharge velocity.

Cutter motor.—The cutter motor is rated at 1,000 h.p. and runs 450–600 r.p.m. on 600 volts d-c. It is designed for especially severe duty encountered as a result of being mounted on the ladder and exposed to the elements in addition to severe electrical and mechanical shock loads.

Some of the cutter motor specifications are:

Suitable for continuous operation with shaft in any position between horizontal and 45 deg. axial tilt.

Weatherproof construction.

Class B insulation with moisture resistant varnish treatment and marine parts.

Motor designed good for 1,500 h.p. for 5 min a[illegible] [illegible]00 h.p. for one min.

Severity of shock loads which must be withstood by the cutter motor can be appreciated by the fact that the cutter is driven by a solid steel shaft 15½ inches in diameter from the cutter side of the gear box.

The cutter has an additional "high-production" feature. The dredge operator watches his cutter tacho-meter and causes the swinging winch to pull the cutter into the material at such a rate that the cutter operates at the current limit point for the speed chosen. Thus the drive is forced to operate at the peak horsepower for the particular speed chosen.

Another desirable feature of the cutter control is a "suicide" connection to limit circulating current, when the master switch is in the "off" position. The cutter drive has no brake and very little friction. To prevent residual generator voltage from circulating current and causing the cutter to creep, the suicide circuit is established when the master switch is in the "off" position. This is especially desirable in view of the frequent cutter teeth inspection and short-duration maintenance tasks.

Speed control is an advantage because of the varying nature of the channel bottom from solid rock to clay and sand.

Swing winch motors.—The swinging winch (sometimes referred to as the hauling winch) is powered by two 187·5 h.p. 230 volt motors in series with the 325 KW swinging winch generator. This drive has a peak momentary capacity of 800 h.p.

The speed-load characteristic is similar to the cutter characteristic and thus maintains a taut line on the swing at all times regardless of load. This protects the swing wire ropes from sudden jerks.

The proper synchronization of swinging speed and cutter speed is therefore an important part of the art of cutter dredging.

In normal operation, reversing of the swinging winch is accomplished by pneumatically operated clutches at the two winch drums. Electrical reversing is for maintenance work and specialized dredging operations.

Power for the Hydro-Quebec comes from the Beauharnois Power House at 44 KV to a mobile substation on a 50-ton trailer. This trailer has mounted on it a fan-cooled transformer and a circuit breaker and associated control.

From the transformer secondary, a single 138,000 volt submarine cable 4½ in. in diameter is laid

The requirements of the magnetic fluid are that it should be capable of wetting the surface of the test piece quickly and permit easy mobility of the particles in it. The suspended particles should be of a fine size and possess high magnetic permeability. A particle size between 3 mu and 6 mu is adequate for industrial use. The time taken for the particles in the suspension to settle is adjusted to c. 30–45 min.

Magnetite has been used as the base material. It is crushed and powdered to a very fine size and the gangue is separated. Various methods—wet, dry and magnetic separation—were used to remove the impurities present in the crushed ore. The purified powder is then heated in a furnace to about 1,750°F. and allowed to cool slowly to room temperature. It is then ground in a liquid medium in a specially designed close-circuit ball mill. When a particle size of 6 mu and below is reached, grinding is stopped and all the particles below 6 mu are separated by sedimentation or elutriation.

The liquid vehicles which conform to prescribed specifications are light petroleum, fraction-distilling between 150° and 260°F., powerine or white spirit. The liquid chosen is treated with sodium hydroxide to remove sulphur and other acidic constituents and a small amount of aluminium stearate or zinc stearate added to raise its viscosity. The stearate is mixed with the liquid, stirred for 24 hr. and processed at 215°F. to form a stable gel. To 100 ml. of this gel are added 1·70 to 2·40 ml. of magnetite powder and the mixture stirred thoroughly.

The setting time of the solid particles in the fluid ranged from 25 to 35 min. The settling characteristics can be varied, as required, by the addition of a positive sol. as the magnetite particles carry positive charge.

Field tests have been carried out with this liquid at the workshop of the Indian Airlines Corporation, New Delhi, on aircraft and other machine parts. The results of these tests have shown that the fluid is comparable to imported brands in its performance.

The cost of preparing the magnetic fluid on the basis of a unit producing 100 gallons per month works out to about Rs. 6 or Rs. 7 per gallon as compared to Rs. 25 to Rs. 40 per gallon for imported fluid. A capital outlay of Rs. 16,000 will be required for such a unit.

"*Journal of Scientific and Industrial Research. A-General*",
May 1955.

How to organise your new power plant.

Tips on Co-ordinating Station construction and start ups.

If future needs are not anticipated properly, getting a new station under way can be one long tale of woe. Here's some advice from an engineer who has followed up many such jobs.

Copies of all new plant orders, specifications, instructions, design prints and letters should be sent to the Plant Operating Superintendent promptly. Advising him of your plans in advance of actual construction helps him make suggestions or objections.

Superintendent's records are also more complete with this information. His files aid in settling questions that often arise during starting and testing. Besides they are valuable for future operation and maintenance.

Design changes.—Before and during construction, you are likely to discover a few items that must be changed to assure safe operation. And during construction other worthwhile improvements may become apparent that can be made without additional cost or delay.

Usually a job can be laid out a number of ways. Just because the design differs slightly from that most liked by operators, start up men, service engineers and others is not always reason enough to warrant extensive changes.

Construction requirements.—Assuming proper design, the Construction Superintendent must build the plant, as designed, in a safe and workmanlike manner. He should do this promptly and at minimum cost to the owner. The manner of construction has a considerable effect on starting, testing and ultimate operation.

Items damaged during shipment or installation should be adequately repaired or else replaced. Faulty equipment causes trouble sooner or later, possibly at a time when a shutdown may be embarassing and costly. Installed equipment should be clean, level and solidly set. All required connections should be in place and the moving elements lined up, cleaned and lubricated. Preferably, operators should assist in this work to become familiar with the new equipment. Take special pains that grease and debris, such as rags, bottles and welding rods, are not left inside of apparatus.

Construction completion.—It is usually uneconomical to completely finish a new project before placing it in operation. Set up the construction schedule to cause minimum interference with early operation. Locker rooms, floors, stairs, and railings should be finished. Remove unnecessary scaffolding, and apply heat insulation where possible. Piping should have been carefully cleaned before erection, then hydrostatically tested and flushed with water or air to clean out refuse.

Well before starting date, expedite installation of instruments, small piping and miscellaneous electrical work, including control wiring and lighting. These items usually take longer than expected and are essential to safe operation.

Start-up co-ordination.—A month to six weeks before the start-up date, hold conference of key operators, start-up men, contractors, manufacturers' representatives and construction men. A definite schedule for start-up activities with proposed dates for each step should be set up.

Request for service engineers of various manufacturers should be made far enough to advance to have them at the plant several days before start-up. This gives them time to look over the installation and make necessary changes before actual operation.

Construction to operation.—As each section of the plant is completed it should be turned over to the operators. Thereafter, let construction men do no work on that equipment without obtaining clearance from the operators. What to do and when should be clearly understood. In this way, you avoid accidents to personnel and damage.

Construction men should be excluded from operating areas after equipment is turned over to the operators, except where work items remain to be done. Any construction work in operating areas should cause minimum interference.

When extending an existing plant, it is advisable to install separating partitions to isolate dirt and noise of new construction work from operating sections of the plant. Shop, warehouse and toilet facilities for construction workers should be adequate, so there is no need for these workers to be in operating areas.

Occasionally, use of existing walks, stairs or elevators by construction personnel is necessary, but it should not interfere with operation.

" *Power* ", July 1953.

Tit-Bits.

Tree farming for hydro-electric utilities pays off thrice. It conserves rainfall for power, aids other water users, and pays for itself in timber sales.

Insulating oil produced in a year falls short of one-tenth the daily production of fuel and lubricating oils.

Participation of all machines in the regulation and minimizing of governor dead-bands is a major contributing factor toward good control of system frequency and tie-line power.

Solar energy to land areas totals ten thousand times man's present energy requirements.

Piston-ring wear is being determined by running a radio-active ring in an engine and then measuring the radio-active enhancement of the crankcase oil.

Galvanized transmission towers (1,300) on one system showed a 30-year life for 45 per cent and over 32 years for 20 per cent before painting was required.

Neutral unbalance between identical Y-connected halves of an underground capacitor bank gives protection where the system neutral is not available.

" *Turbovision* " *is the British name* for turbine supervisory instruments.

" *Electrical World* ", April 11, 1955.

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Social and Personal

Sri M. B. Kandaswami, Chief Operation Engineer (South), retired from service on 27th August 1955 and re-employed as Chief Operation Engineer (South) for one year.

On reversion from Andhra State, Sri T. Krishnaswami was posted as Superintending Engineer, Papanasam Electricity System, *vice* Sri P. V. A. Narayanamurthi proceeded to Damodar Valley Corporation for appointment as Deputy Chief Engineer.

Sri K. V. Karantha, Chief Electrical Inspector to Government, retired from service with effect from 22nd July 1955 afternoon.